Contents Print

IMPREGNATION METHODS, RESINS AND EQUIPMENT

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Abstract: In the early 1990's many of the solvent based resins that were being used were converted to quick cure formulations. These new formulations created lower VOC (Volatile Organic Compound) emissions, lower cure temperatures, and shorter processing times. The savings in energy for curing parts on average resulted in an immediate savings of approximately 25%. The effects on the equipment and machines processing parts were numerous. Exhaust emissions were reduced, heat losses were reduced, cure times became much shorter, and some new components were able to be used on the machines that were not previously used due to the lower operating temperatures. Since that time, the changes that have taken place have not been as many as at that time, however, improvements continue to be made in optimizing operating energy efficiencies, better control and handling of resins, reducing waste, and more informative data monitoring and acquisition.

The topic of this paper was previously presented in 2004 by Jeff Schein of HeatTek and the author. This paper will update those topics discussed at that time and include some of the new areas of emphasis seen today in designing and building Varnish Impregnation Systems.

Key words: Trickle, Dip, Roll, VPI, Ovens, Curing, Varnish, Epoxy, Resins.

I. INTRODUCTION AND TYPES OF RESIN

Industry and market standards will quite often dictate the type of coating that will be applied on a particular part. For example, a heavy duty alternator that sees a harsh environment, temperature extremes, and varying electrical demands will most often require an epoxy coating. A power tool seeing periodic use for short time intervals is more likely to use one of the quick cure polyester resins. Large traction motors too big for normal processing methods and very costly to purchase or refurbish will most likely use an epoxy coating in a VPI system. Each of these processes demand significantly different processing equipment. This paper will discuss the different types of equipment and systems used today for coating motor or transformer components with the different resins. The resins that will be evaluated include discussions on: solvent based resins, quick cure resins, heat cured epoxies and water based epoxies, and water borne resins. A brief description of each resin and the impact that resin has on equipment designs will be provided. Next, processing methods will be discussed including: Dipping, Roll Coating, Trickle Impregnation, and Vacuum Impregnation. The discussion will continue with the most common types of equipment and components used for each of the five resins listed. Descriptions of various curing methods, resin application equipment, cooling methods, part handling methods, and data monitoring/acquisition equipment will be reviewed.

A. Polyesters and Epoxies.

1. Solvent Based Resins

Solvent based resins have been the primary type of resin used in manufacturing of motors since the early times. The resins relied mainly on xylene, naptha, styrene or vinyl toluene thinners for maintaining viscosity. These resins usually cure to a golden brown color along with all of the equipment that the solvent was exposed too. Keeping solvent based materials within an acceptable quality range requires monitoring the percentage of solvents present in the mixed resin and adding more solvent when required to maintain the viscosity. New quick cure formulations of these resins are not all that much different than the original formulations with the exception of certain additives that allow the solvent to chemically crosslink with the base resin and thus tie up the majority of the loose solvents. The new resins cure with a lighter color and less residue left on the process equipment.

2. Heat Cured Epoxy

Heat cured single part epoxies have long been used in applications where the part will see extreme conditions. In process, one part epoxies are usually of a higher film build, usually thixotropic (meaning that it will thin as it is stirred), and requires little monitoring to maintain quality. Heat cured epoxies are typically cured at higher temperatures for longer periods of time. Without meeting these conditions the one part epoxy will not cure.

Two part epoxies are also used quite often and provide varying film build up based on the starting viscosity and the rate at which the two components cure. A catalyst is mixed with the resin that may be reactive enough that heat is not required. In most cases, however, a brief heating period will aid in curing the resin. Meter mixing of the two parts is common on automated assembly lines. Most epoxies are dispensed at fairly close ratios and volumes so metering the two components are not as difficult to do as with polyesters mixing at 50:1 ratios. Highly reactive epoxies need to have the lines purged periodically in between cycles based on the reaction time. This causes some waste but is necessary to keep the automated lines operational.

3. Water Based Resins

Water based resins were developed as low VOC alternatives. The resultant coating tends to be a clear light film build left on the part after the water evaporates. Handling of the water based resins requires only monitoring the viscosity and the percentage of water to solids. Equipment used with water based systems usually requires the least amount of metering equipment and control.

4. Quick Cure Polyesters

Quick cure polyesters have become the back bone of most of the polyester coated parts. Earlier versions of the quick cure resins were fairly reactive with a shelf life of only minutes using MEK peroxide as a catalyst to 3 – 5 days with the standard TBP catalyst. The newest third generation of resin provides up to 20 day mixed shelf life and reduces the maintenance requirements and some of the cooling eqiupment needed to keep the resin from gelling.

5. Water Based Epoxies

Water based epoxies became quite widely used in the hermetic motor industry in the past 10 years. The water based epoxies offer superior qualities and cure in as little time as one hour at lower temperatures when compared to the one part epoxies. The trade off in many cases, however, is in a lighter coating and film build.

The following table gives a comparison showing the differences in the bake times and temperatures for the various types of resins previously described.

Table 1. Comparison of resin cure times and temperatures.

Resin Type	***Cure Time***	***Cure Temp.***
Solvent Based	*1 -2 hours*	*350 F.(177 C.)*
Heat Cured Epoxy	*2 - 3 hours*	*350 F.(177 C.)*
Water Based	*1 hour*	*250 F.(122 C.)*
Quick Cure	*10 min.*	*250 F.(122 C.)*
Water Based Epoxy	*1 hour*	*300 F.(149 C.)*

II. Discussion - PROCESSES AND EQUIPMENT

A. Processing Methods

Each of the resins described above can be processed under different handling and curing methods. Some of these methods work better due to the size of the part being processed, production rates, or cure times. Current trends in processing methods, conveying, resin handling and curing systems will be explored further in the following section.

1.Epoxy and Polyester Dip and Bake Systems

Dipping of preheated or ambient temperature parts in resin is the most common and oldest form of mass treating parts. Parts are either conveyed through a trough or moved into position and submerged in a tank of resin. This fairly common when processing larger parts and high volume parts. Parts are then allowed to drain for a period of time before moving into the cure chamber. Parts are usually loaded onto a hanger. In the case of low production parts, quite often these are dipped in a stationary tank by an overhead crane, allowed to drain, and loaded onto a cart or directly into an oven for curing.

2. Dip, Roll and Bake

Similar sized parts such as starter motor or power tool armatures that are produced in high volumes are quite often ideal for roll coating. Rolling a part in resin can prevent varnish from going into places where it is not desirable such as on the shaft of an armature or the I.D. of a stator. Larger parts or high production armature rotors quick cure resins are most often processed by this method. Transferring the part after it has been coated is usually done only after the resin has gelled. Roll coating has become more common in the last few years due to the ability of the parts to pick up more resin potentially than in the trickle process. Roll coat systems tend to require less moving parts and equipment but quite often introduce cooling of the resin as a part of their normal operation.

3. Trickle Impregnation

Applying resin by dispensing it in a controlled amount onto a part in the correct areas for a predetermined amount of time is called trickling. Trickle references the controlled amount of resin being dispensed and is usually one or multiple small streams of resin being pumped out of hose or tubing. Controlling the location of the resin being applied prevents resin from going into unwanted areas and consequently reduces additional cleanup work needed to be done to the part after curing. Quite often machining operations are eliminated and balancing of armatures is improved due to the controlled distribution of resin. Parts are most often individually held and rotated during this time at a controlled RPM.

4. Vacuum-Only and Vacuum- Pressure Impregnation

VPI (vacuum pressure impregnation) is generally used in two distinct product lines. The first line includes types of dry type transformers while the second type of product includes motor and generator impregnation. The VPI process is carried out by placing parts into a vacuum/pressure vessel, closing and sealing of the domed cover, drawing a vacuum on the chamber, which evacuates the air, and then filling the chamber with resin. In the absence of air, resin fills all of the open areas of a part submerged in liquid and is the best method of saturating a tightly would part. The key reason this process is used is the same for both of the products mentioned above that being maximum resin penetration into the coil system as quickly as possible. Current transformer and motor designs pack more copper and insulation into smaller areas making the VPI process a critical processing method for these types of parts. .

B. Conveying Methods

The handling and conveying of parts is unique to each production line and critical to flow of the product through the production line. Variables that define the type of conveying system include: the type of resin, the part size, and the production rate. There are three primary methods of conveying parts:

1. Overhead conveyor

Over head chain conveyors are either I-beams, enclosed track, or formed tubing with a driven chain with attachments. Hooks or hangers are hung from the chain and parts are then hung from the hangers. The conveyor lines travel a rates determined to carry the calculated number of parts to meet the production rate.

Quite often the chain travel is started and stopped instead of continuous travel. When this is done, parts are usually dipped at a single station when the chain is not moving. Quick cure resin systems are quite often designed this way. With the resin typically having a limited shelf life, minimizing the size of the mixed resin increases the turnover of the tank. Larger tanks need to be designed differently for environmental and fire prevention purposes. Withdrawing the parts from the resin at controlled rates will have an affect on the amount of resin left on the part after the coating process.

2. Part Racks/Trays

Batch ovens and indexing overhead conveyor lines utilize carts loaded with multiple levels of racks or single carriers loaded with parts. Transformers, large parts and smaller parts that can be nested close together are typically processed this way.

3. Individual Part Fixturing

Parts that are to be trickled need to be held and rotated during the coating process. On automated systems, fixtures can take many forms and are most often secured to a rotator (for a single station) or a set of chains that are used to convey the fixtures. Stators require grippers that secure to the inside diameter or around the outside diameter. The grippers are either spring loaded or manually expanded. Rotors and armatures require collets that can hold varying shaft diameters and lengths. Designing the grippers properly with springs, magnets, or bushings prevent parts from falling from the part fixture as they rotate.

C. Resin Handling

Automated resin systems most often require automatic meter mixing while less automated lower production systems can utilize manual filling of resin tanks or holding containers. The amount of resin used and in house chemical handling policies quite often dictate which method is acceptable.

1. Meter Mixing

Meter mixing is completed by forcing a resin and a catalyst together at a controlled ratio. Pump styles include: piston, peristaltic, diaphragm, or gear pumps controlled at the proper speeds for the required ratio control. The ratio and the accuracy required during the mixing will help decide the best style of pump. Mixing rooms, ventilation control and fire protection are always included in this part of a system.

2. Dip Tanks

Tanks are sizes are normally made only large enough to submerge the parts. Automated systems usually incorporate constant overflowing resin with a maintained level. The overflowing resin typically flows back to a holding tank with automatic level controls. In warm climates or if preheated parts are dipped into the tank, the overflowing resin is forced through a heat exchanger designed to remove the heat gained from the parts dragged through the resin. Cooling resin will extend the life of the batch. If cooling is not used, then the mix

Contents Print

ratios need to be monitored to insure that solvent or water stay at the correct ratios.

4. Process Monitoring and Data Acquisition

Knowledge of the process, part location, and status of the operation at any location is known today through the use of PLC's and data acquisition software. Conveyor speed, cycle time, part count, resin/tank information, and alarm conditions are all common features tracked in the PLC system. Data acquisition software that takes signals from the PLC relays this information to PC's. Remote alarms can be programmed along with SPC information.

5. Vacuum-Only and Vacuum- Pressure Impregnation

A VPI system will include a vacuum chamber, resin holding tank, vacuum pump, and control valves for transferring resin. The resin is passed thru a pipe connecting the tanks by use of differential pressures. In some systems, vacuum and pressure is used in the process, control of the depth of vacuum and the dryness of the compressed air have become critical in maintaining the resins chemical balance. In most applications, the resin is stored in a reservoir equipped with a cooling and agitation system to maintain the resin at a proper temperature

D. Heating Methods

With more emphasis being placed on energy savings and minimizing process times and floor space, quite often combinations of heating methods prove to be the quickest and most efficient way to heat parts before or after coating. The following heating methods are used alone or in combination on curing systems today.

1. Convection Ovens

Convection ovens describe either gas or electrically heated ovens that circulate air inside a curing chamber. The heat up rate of a part is a result of the velocity of air traveling past the part and oven temperature set point. Different resins require a specified temperature for varying amounts of time. Examples of this are given in Table #1.

2. Infrared Ovens (Gas or Electric)

Radiant heating is heating a part with certain frequency light waves. Infrared heating rates are usually limited to the maximum surface temperature the part can with stand without damage to the wire, phase paper and insulation. Infrared heat is most often limited to use with smaller parts with less mass. Quartz lamps, ceramic , sheathed elements, and catalytic gas panels are all methods of Infrared heating panels.

3. Induction Heating

Induction heating takes place when the magnetically conductive components of a part are placed inside of a magnetic field. Heating of the most conductive components of a part are heated vary quickly and conduct that energy into other areas of the part. Induction coils and power supplies are custom designed and sized for each application. Controls allow power to be applied continuously or intermittently for pulse heating.

4. Resistance Heating

In theory, resistance heat can be considered the opposite of induction heating. Instead of heating the steel laminations first, leads are connected to the copper winding which is then energized and heated as a resistive load. Lead wires are attached to a power supply or contact is made by the use of brushes. A controlled amount of power is then applied to heat the part. Resistivity is monitored and checked for the desired final temperature. Large parts are quite often heated by this method since the winding is the primary area of the part to be heated.

III. CONCLUSIONS

Although the methods of processing and the coatings do not change in concept all that frequently, there are numerous continuing improvements that have been made in the past few years. Electronic process control and monitoring give us live process information that was never available previously. Knowing some of this information, such as when a part reaches temperature or a part reaches a certain location in a process, allows control to be added to operate a machine with the least amount of energy and cost. Resin formulations drive innovation creating new opportunities for new equipment design.

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Peter Caine received his BS in Industrial Engineering from the University of Wisconsin –Platteville and has been involved in the Heat Processing industry since 1986. His professional career includes Application Engineering, Sales, and Electric Motor Division Manager Positions at Oven Systems Inc. His current

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